Journal of Pioneering Medical Sciences
Received: April 30, 2025 | Accepted: September 07, 2025 | Published: November 05, 2025
Volume 14, Issue 10, Pages 143-147

DOI https://doi.org/10.47310/jpms2025141019

Efficacy of Nano Silver Fluoride Versus Silver Diamine Fluoride in Prevention of Dental Caries: A Comparative Study

Romeshkumar Narayanbhai Chaudhary[1], Queentaj Dutta[2], Nitin Lingayat[3], Haifa B[4], Smita Durga Dutta[5], Pooja Kadam[6], Ganaraj Shetty[7] and Rahul Tiwari[8*]

[1]AMC Dental College & Hospital, Ahmedabad, India
[2]Department of Conservative Dentistry and Endodontics, Government Dental College, Dibrugarh, Assam, India
[3]Department of Paediatrics, Symbiosis Medical College for Women and Symbiosis University Hospital and Research Centre affiliated to Symbiosis International (Deemed) University, Lavale, Pune, India
[4]Department of Prosthodontics, College of Dentistry, Qassim University, Kingdom of Saudi Arabia, Saudi Arabia
[5]Department of Conservative Dental Sciences and Endodontics, College of Dentistry, Qassim University, Kingdom of Saudi Arabia, Saudi Arabia
[6]Department of Periodontology, Dr D Y Patil Dental College and Hospital. Pimpri. Pune, Dr D Y Patil vidyapeeth Pimpri, Pune, India
[7]Department of Prosthodontics and crown & bridge, Nitte (Deemed to be university) AB Shetty memorial institute of dental sciences, Deralakatte Mangalore, India
[8]Department of Oral and Maxillofacial Surgery, RKDF Dental College and Research Centre, Sarvepalli Radhakrishnan University, Bhopal, Madhya Pradesh, India

Author Designation: [1]Adjunct Professor, [1]Lecturer, [3,5]Assistant Professor, [4,6]Associate Professor and [7,8]PhD

*Corresponding author: Rahul Tiwari (e-mail: drrahulvctiwari@gmail.com).

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Abstract **Background:** Dental caries (DC) remains a widespread pediatric health issue, particularly in underserved populations. "Silver diamine fluoride (SDF)" is effective in caries arrest but associated with unaesthetic staining. "Nano silver fluoride (NSF)" has emerged as a promising alternative with enhanced antimicrobial activity and improved esthetics. **Aim:** To compare the efficacy, safety, and esthetic outcomes of NSF versus SDF in preventing DC in primary teeth. **Methods:** A randomized, controlled, double-blind clinical trial was conducted among 80 children aged 4-8 years with active carious lesions. Participants were divided into two sets: Set A received NSF (600 ppm), and Set B received 38% SDF. Lesions were evaluated using ICDAS-II criteria at baseline, 3 months, and 6 months. Primary outcome was caries arrest rate; secondary outcomes included discoloration and adverse effects. **Results:** Both sets demonstrated high caries arrest rates (NSF: 90.0%, SDF: 90.3%, p = 0.94). However, SDF showed significantly higher discoloration incidence (p<0.001). Adverse effects were minimal and statistically non-significant between sets. **Conclusion:** NSF demonstrated equivalent efficacy to SDF with significantly better esthetic outcomes, making it a promising agent for non-invasive caries management in children. Beyond individual clinical use, NSF's esthetic acceptability and ease of application position it as a valuable tool for school-based and community oral health programs, particularly in populations where treatment compliance and social acceptance are critical.

Key Words NSF, SDF, Dental caries, Caries prevention, Pediatric dentistry, Non- invasive treatment, Esthetics, Antimicrobial agents, Fluoride therapy, Clinical trial

INTRODUCTION

DC remains one of the most prevalent chronic diseases globally, affecting individuals across all age sets, particularly children in early developmental stages. Despite advances in oral healthcare, socioeconomic disparities, limited access to fluoride treatments, and poor dietary habits contribute to a persistent high incidence of caries, especially in low- and middle-income countries [1]. Preventive interventions such as topical fluorides have been cornerstones in caries management. Among them, SDF has gained widespread clinical use due to its high cariostatic efficacy. However, aesthetic concerns like black staining of carious lesions and potential cytotoxicity have prompted the exploration of alternative agents [2].

NSF has emerged as a promising innovation in the field of preventive dentistry. It integrates the antimicrobial properties of silver nanoparticles with the remineralizing capacity of fluoride, offering a dual-action mechanism. The nanoscale size of silver particles in NSF enhances its surface area and reactivity, improving its ability to penetrate the biofilm and exert sustained antibacterial action against cariogenic organisms like *Streptococcus mutans* [3]. Moreover, NSF

has shown the capacity to promote enamel remineralization while avoiding the discoloration typically associated with SDF application [4].

Comparative evaluations between NSF and SDF have become increasingly relevant due to their shared use in non-invasive, community-based dental programs. Studies have reported that both agents are effective in arresting active carious lesions, especially in primary dentition, yet NSF may offer added advantages in terms of esthetics and biocompatibility [5]. However, existing knowledge gaps remain, particularly regarding long-term randomized controlled trials on NSF, its cost-effectiveness, and large-scale community-based applications. Clinical trials have demonstrated that NSF can significantly reduce lesion progression in early childhood caries without causing tooth discoloration or adverse tissue reactions [6].

Furthermore, the development of higher-concentration NSF formulations has improved its anticariogenic potential, achieving arrest rates comparable to or even surpassing that of SDF in controlled settings [7]. Unlike SDF, which primarily relies on silver ions and fluoride for its mechanism, NSF benefits from the synergistic interaction of nanosilver particles, which disrupt bacterial cell membranes and inhibit biofilm formation, and fluoride ions, which enhance enamel resistance through remineralization [8].

Quality-of-life studies have also shown that subjects treated with NSF report better acceptance, primarily due to the absence of staining and irritation, which can be significant concerns with SDF, especially in anterior teeth [9]. Additionally, NSF's suitability for incorporation into gels, varnishes, and dentifrices makes it a versatile agent in both clinical and home-care settings. The potential of NSF to offer equal or superior efficacy to SDF without compromising esthetics underlines the importance of further comparative clinical research [10].

This research aims to critically evaluate the preventive efficacy of NSF in comparison with SDF in the prevention of dental caries. By focusing on clinical outcomes such as lesion arrest, patient acceptability, and side-effect profiles, the research contributes to the growing body of evidence guiding the selection of non-invasive caries management strategies.

METHODS

Research Design and Setting

This research was designed as a randomized, controlled, double-blinded clinical trial conducted over a 6-month period in a community dental health center. Ethical approval was obtained from the institutional ethics committee, and the research followed the guidelines set forth by the Declaration of Helsinki. Informed consent was acquired from the parents or legal guardians of all participating children.

To maintain allocation concealment, assignments were placed in sequentially numbered, opaque, sealed envelopes (SNOSE), which were opened only at the time of intervention by a staff member not involved in clinical evaluation. Both participants and examiners were blinded to group allocation.

Sample Selection

A total of 80 children aged 4 to 8 years presenting with at least one active non- cavitated or cavitated dentinal carious lesion in primary molars were recruited. Inclusion criteria included children in good general health, with no systemic illness, and no history of allergy to silver-based products. Exclusion criteria included presence of abscesses, fistulae, or pulpally involved teeth in the same quadrant.

Randomization and Set Allocation

Participants were randomly assigned into two sets (n=40 each) using computer- generated block randomization.

- Set A received application of NSF solution at a concentration of 600 ppm
- Set B received 38% SDF solution

Both agents were applied following standardized protocols under aseptic conditions.

Intervention Protocol

Prior to application, the selected carious tooth surface was cleaned using a cotton pellet and isolated with cotton rolls. A microbrush was used to apply 1–2 drops of the assigned solution directly to the lesion, ensuring full coverage. No mechanical removal of carious tissue was performed. Subjects were instructed not to eat or drink for at least 30 minutes post-application. Applications were repeated at baseline and 3- month intervals.

Clinical Evaluation and Follow-up

Lesion activity was assessed at baseline, 3 months, and 6 months using the International Caries Detection and Assessment System (ICDAS II) criteria. A blinded examiner, calibrated with a kappa value of >0.80 for inter-examiner reliability, recorded whether the lesion was active (soft and yellow/brown) or arrested (hard and black/brown for SDF, hard without discoloration for NSF). Adverse effects, such as gingival irritation, tooth discoloration, or sensitivity, were also recorded.

Statistical Analysis

All data were compiled and analyzed using SPSS version 26. Descriptive statistics were calculated for demographic data. Chi-square test was used to compare caries arrest rates between the two sets. A p-value of <0.05 was considered statistically significant. Effect sizes (risk differences, relative risks) with 95% confidence intervals were calculated in addition to p-values to improve interpretability of clinical outcomes.

RESULTS

Demographic Characteristics

The mean age was comparable between Set A (NSF) and Set B (SDF), with no significant difference observed (p = 0.64). The gender distribution was nearly equal in both sets, and statistical analysis confirmed that the demographic characteristics were well matched at baseline (p>0.05 for all variables) (Table 1).

Caries Arrest Rates

At the 6-month follow-up, Set A (NSF) showed a caries arrest rate of 90.0% (54/60 lesions), and Set B (SDF) demonstrated 90.3% (56/62 lesions). The absolute risk difference was –0.3% (95% CI: –10.5% to +9.8%), with a relative risk of 0.99 (95% CI: 0.85–1.15; p = 0.94), indicating no clinically meaningful difference between groups (Table 2, Figure 1).

Incidence of Tooth Discoloration

Discoloration occurred in 5.0% of NSF-treated children versus 87.5% of SDF-treated children. The relative risk of discoloration with NSF compared to SDF was 0.06 (95% CI: 0.02–0.15; p<0.001), confirming a large and statistically significant esthetic advantage for NSF. (Table 3, Figure 2).

Adverse Effects

Minor adverse effects were reported in both sets. Gingival irritation occurred in 1 child in the NSF set and 3 in the SDF set. Tooth sensitivity was reported by 2 children in Set A and 4 in Set B. The differences were not statistically significant (p>0.05). The majority of participants in both sets reported no adverse effects. (Table 4, Figure 3).

DISCUSSION

The present research compared the efficacy of NSF and SDF in preventing and arresting DC among young children. Both agents demonstrated high caries arrest rates with no statistically significant difference, suggesting comparable clinical effectiveness. These findings are supported by prior trials reporting similar outcomes in arresting dentinal caries in primary molars [11,12]. The comparable performance may be attributed to the dual-action mechanism shared by both agents fluoride-mediated remineralization and silver-based antimicrobial activity [13].

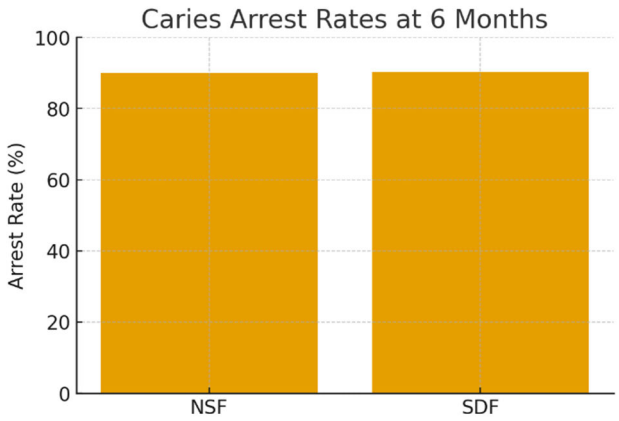

Figure 1: Caries Arrest Rates at 6 Months

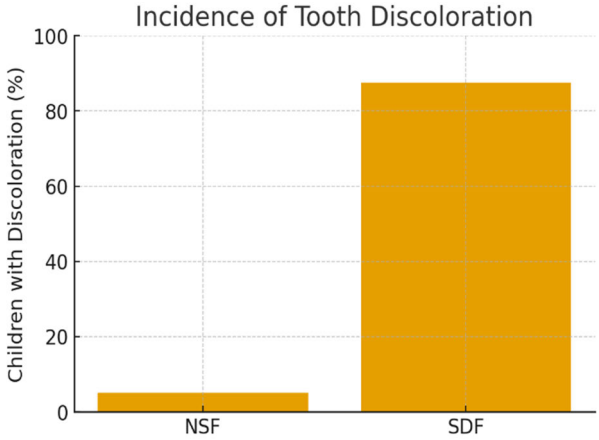

Figure 2: Discoloration Incidence

Table 1: Baseline Demographic Distribution

Variable	Set A (NSF)	Set B (SDF)	p-value
Age (mean±SD)	6.2±1.1	6.3±1.2	0.64
Gender - Male (%)	22 (55%)	21 (52.5%)	0.82
Gender - Female (%)	18 (45%)	19 (47.5%)	0.82

Table 2: Caries Arrest Rates at 6 Months

Set	Total	Arrested	Arrest Rate	p-value
Set A (NSF)	60	54	90.0%	0.94
Set B (SDF)	62	56	90.3%	

Table 3: Discoloration Incidence

Discoloration Observed	Set A (NSF)	Set B (SDF)	p-value
Yes	2	35	<0.001
No	38	5	

Table 4: Adverse Effects Reported

Adverse Effect	Set A (NSF)	Set B (SDF)	p-value
Gingival Irritation	1	3	0.30
Tooth Sensitivity	2	4	0.39
No Adverse Effect	37	33	0.18

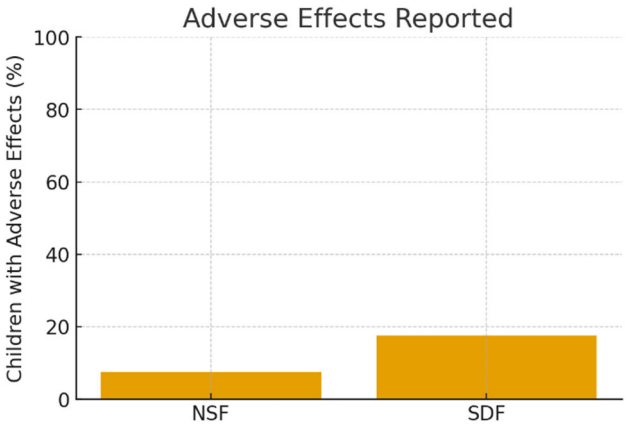

Figure 3: Adverse Effects Reported

However, a significant difference was observed in terms of esthetic outcomes. SDF caused substantial black discoloration of treated lesions, affecting the acceptability among subjects and parents. This aligns with multiple reports identifying staining as a major limitation of SDF, particularly in anterior teeth [14]. NSF, in contrast, exhibited minimal or no discoloration, reaffirming its advantage in esthetically sensitive zones. Recent advancements in nanotechnology have enabled the synthesis of silver nanoparticles with high antimicrobial efficacy while maintaining translucency on tooth surfaces [15]. These particles disrupt bacterial membranes and interfere with DNA replication, making them potent against *Streptococcus mutans*, without leaving permanent stains [16].

Although both groups achieved similar caries arrest rates, the narrow confidence intervals indicate high precision of effect estimates. Importantly, the large effect size and narrow CI for discoloration strongly support the esthetic superiority of NSF.

In terms of safety, both agents demonstrated minimal adverse effects, with no significant differences between sets. Previous studies evaluating cytotoxicity profiles of nano-formulated fluoride compounds have confirmed that NSF exhibits low cytotoxicity at therapeutic concentrations [17]. Additionally, NSF has shown promising results in sustained fluoride and silver ion release, which may prolong its therapeutic window without repeated applications [18].

Parental and patient acceptability plays a crucial role in pediatric dentistry, particularly for preventive interventions applied to anterior teeth where esthetics are highly visible. In the present trial, although both agents demonstrated similar caries arrest rates, the high incidence of black discoloration with SDF could negatively influence treatment acceptance by parents. Prior studies have consistently reported that caregivers prefer treatment options that avoid permanent staining, even if efficacy is equivalent [1,2]. NSF, by maintaining esthetic integrity while achieving comparable caries arrest, may therefore improve parental satisfaction, enhance compliance in follow-up visits, and increase willingness to adopt community-based preventive programs. These factors are critical in determining the real-world success of pediatric caries management strategies.

From a preventive dentistry perspective, the advantages of NSF extend beyond efficacy and esthetics. Its ease of application, minimal need for tooth preparation, and potential to be incorporated into varnishes, gels, and dentifrices make it suitable for both professional and home-based caries management [19]. Moreover, its stability and shelf-life make it particularly beneficial for community dental health programs in low-resource settings, where refrigeration and infrastructure are limited.

While this research strengthens the case for NSF as a viable alternative to SDF, certain limitations must be acknowledged. The follow-up duration was limited to six months, which, although clinically relevant, may not fully capture long-term arrest rates or recurrence. Furthermore, microbiological evaluations were not included in this research, and future research should incorporate salivary and plaque sampling to quantify bacterial shifts post-treatment. Comparative cost-effectiveness analysis between the two agents would also be valuable, particularly in public health programs.

The present findings contribute to the growing body of literature supporting NSF as an effective, esthetically acceptable, and safe caries preventive agent. The high arrest rates observed, coupled with its non-staining property, position NSF as a potentially superior alternative to SDF, especially in young children and esthetically sensitive clinical scenarios [20].

CONCLUSIONS

NSF and SDF both demonstrated high efficacy in arresting DC in primary teeth. However, NSF offered superior esthetic outcomes and comparable safety, making it a preferable option, particularly in pediatric patients. Its minimal staining, ease of application, and sustained antimicrobial activity make NSF a valuable addition to preventive dentistry, especially in resource-limited or esthetically conscious settings.

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